Architecture Challenge 2016 “Robotic Contouring”

Andrei Gheorghe
University of Applied Arts Vienna, IoA

Robert Vierlinger
Bollinger + Grohmann Engineers

Philipp Hornung
University of Applied Arts, RWC Lab

Manora Auersperg
Die Angewandte, Textiles Gestalten

Sigurd Reiss
Clever Contour GMBH

1 Robotic Contouring, final structure, upward view

This project investigates the development of three-dimensional profile folding without the use of expensive formwork. A robotic workflow is employed to achieve the production of a highly intricate spatial installation in a fast and efficient fashion. Parametric computation was applied to design the overall configuration towards the detailing and fabrication setup.

The “Robotic Contouring” project was conducted as part of the Architecture Challenge 2016 summer school at the University of Applied Arts in Vienna, in collaboration with Clever Contour GMBH and Bollinger + Grohmann Engineers. The workshop was intended for students interested in exploring digital design and fabrication while simultaneously designing a full-scale built project following an integrated, multidisciplinary process. The workshop was enriched with robotic design strategies combining Grasshopper plugins such as the KUKA|prc and Karamba platforms.

Formally, the project introduces an idea of spatial frames with a high degree of freedom, bending and twisting in space. Applying finite element analysis, a bundling system is used to develop a vertical structure made of light plastic profiles. Textile surfaces were produced with the support of the Department of Textiles Gestalten out of linear elements, creating different spatial and surface effects.

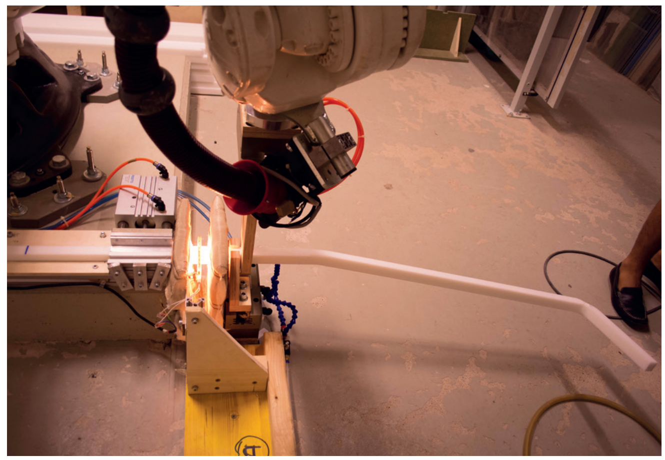
The bundling system is able to produce a continuous structural behavior from two-meter-long 3 x

PRODUCTION NOTES

Status:	Design/Build
Site Area:	3 x 3 x 5.5 m
Location:	Vienna, Austria
Date:	2016

2 Final lightweight structure, suspended

3 Final structure with textile surfaces



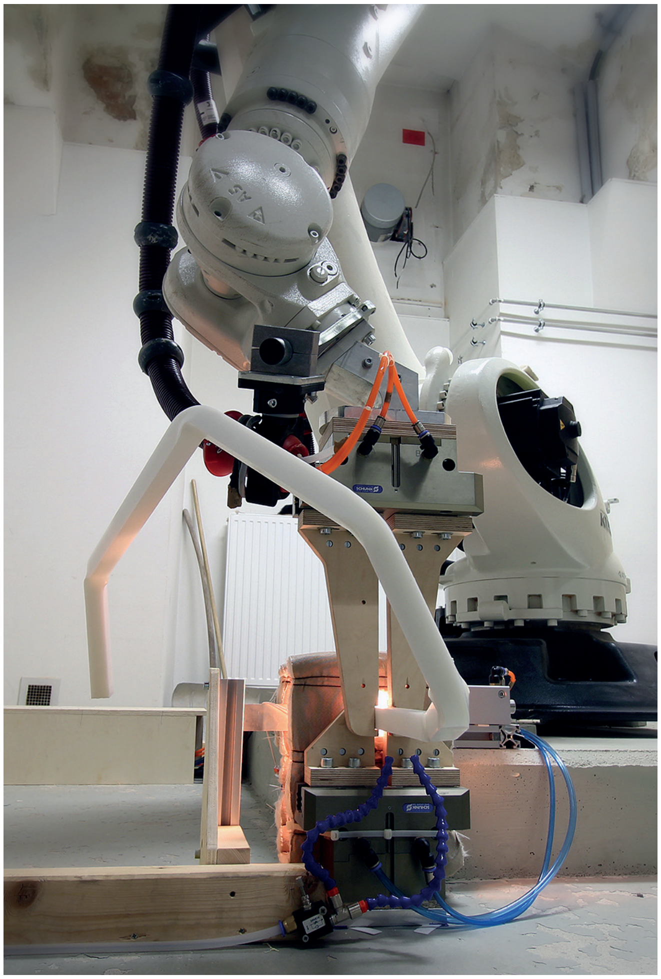
4 Heating process with IR heater ring

3 cm polyethylene plastic profiles. With connections in multiple directions, the structure achieves a height of approximately 5.5 meters. The organization of material and orientation of components were defined with the constant and real-time feedback of the Grasshopper/Karamba structural analysis. Experts from Bollinger + Grohmann Engineers supported the structural optimization process. Design options were tested and improved involving the multi-criteria design optimization tool Octopus, until a maximum displacement of 40 mm (under gravity load) and a material utilization of 40% was achieved.

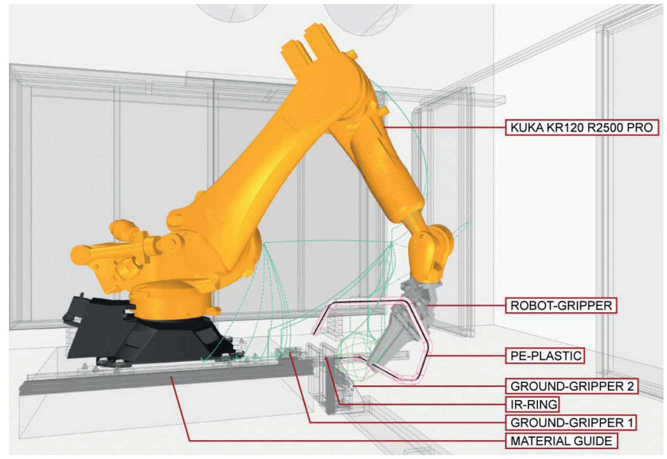
Rationalization of the overall form fed the fabrication system, creating a seamless flow from design to materialization. The geometry was translated into robotic production through KUKA|prc with the help of specialists from the RWC Lab at die Angewandte, allowing the simulation and pre-visualization of each component. The construction setup was developed and optimized using a continuous digital design chain towards full-scale production. The robot setup is based on a new fabrication method developed and patented by Clever Contour GMBH in Vienna for earlier research, conducted with the support of the Austrian Research Promotion Agency. All pieces were fabricated using an automatic production pipeline involving a KUKA robot arm with an IR heater ring to soften the material before bending and an air cooling system to harden the material after the bending process. The process involves the following steps: (1) robot end effectors grab the plastic profile; (2) the profile is pulled by the robot to the exact position for the first bend; (3) the ground grippers nos. 1+2 fix the profile; (4) the IR ring heats up for about 3 minutes; (5) ground gripper no. 2 releases; (6) the robot bends the softened material three dimensionally; and (7) holds it in space until the air cooling solidifies the material and the whole process is repeated for the next bend.

An intense testing phase was required to define the optimal heating time to sufficiently soften the plastic material so that the end effectors of the robot can first apply the bending movement, and then solidify the material by air blasting to achieve enough

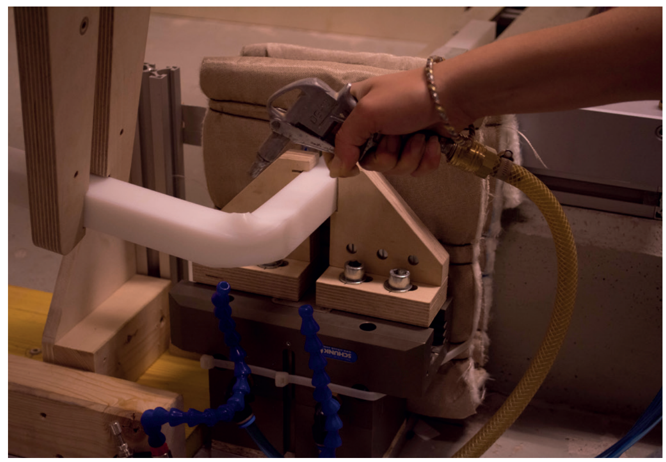
5 Final structure



6 Heating process before bending



7 Robot setup



8 Air cooling after bending

stiffness for the subsequent pulling process. These parameters had to be calibrated according to material constraints, as a thicker/thinner member or a different type of plastic would require time adjustments. The whole process, including pulling, heating, and cooling, requires about 8 minutes per bend, therefore each structural member with 3 bends could be produced in about 30 minutes.

Future research attempts to incorporate hole drilling for element-to-element connection in the fully automated setup. This would remove the need for human-applied clamps for fixation; instead, the pieces could be directly attached and screwed to each other.

Aligned with the aim of the conference, this project envisions novel design methods by developing a new workflow for the production of plastic members, and hereby introducing a new, innovative way of creating freeform geometries. This entirely digital construction process attempts to create a direct link between virtual freeform design and physical full-scale geometrical creation.

www.2016.architecturechallenge.org

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Instructors

Andrei Gheorghe (Universität für Angewandte Kunst Wien, IoA), Manora Auersperg (Universität für Angewandte Kunst, Textiles Gestalten), Robert Vierlinger (Bollinger + Grohmann Ingenieure), Philipp Hornung (Universität für Angewandte Kunst, RWC Lab), Sigurd Reiss (Clever Contour GMBH)

Students

Zvonko Vugreshek, Hristina Kamenova, Jan Kovářiček, Cristina Costea,

9 Robot setup

Ondřej Pokoj, Nicolas Stephan, Judyta Cichocka, Krzysztof Nazar, Victor Sardenberg, Alec Singh , Reem Alkaisy, Tony Guedes, Ioana Mladin, Carmen Mladin, Izabela Kowalska, Jonathan Paljor

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IMAGE CREDITS

Angewandte Architecture Challenge 2016

Andrei Gheorghe is currently teaching as an Assistant Professor at the Institute of Architecture / University of Applied Arts in Vienna. Previously he was Assistant Professor at Portland State University, USA, where he developed pedagogy and research in digital media and fabrication. He studied at the Academy of Fine Arts Vienna, and after being awarded the Fulbright Scholarship at Harvard University, he graduated with distinction and received the Harvard GSD Digital Design Prize. Andrei has taught at various institutions such as Academy of Fine Arts Vienna, SCI-ARC Los Angeles and Harvard Graduate School of Design (Career Discovery Program). Previously, he worked as an architect for international offices such as Jakob + MacFarlane, dEcoi Paris and Foreign Office Architects (FOA) London.

Robert Vierlinger is a researching engineer and interdisciplinary consultant. Working on his PhD at the University of Applied Arts Vienna, he investigates digital representations and evolutionary design strategies. Robert develops the plug-ins Octopus and Octopus.e for Grasshopper, and is also involved in the development of Karamba. Parametric engineering and optimizations for international competitions and construction projects are the basis of his consultancy at Bollinger-Grohmann engineers. He studied structural design at TU Delft and TU Vienna, studied at Studio Hani Rashid Vienna, led workshops in Germany, England, Denmark, Hongkong and Austria, and teaches at Studio Zaha Hadid Vienna.

10 Assembly process of modules

11 Assembly process and textile fixation

Philipp Hornung studied architecture at the Georg-Simon-Ohm University in Nuremberg and the University of Applied Arts in Vienna at the master class of Zaha Hadid, Greg Lynn and Wolf Prix, where he received his degree with distinction. He gained experience at numerous internationally renowned architectural design offices such as Graft Architects and Coop Himmelb(l)au. Since 2014 he has been a research assistant at the "Robotic Woodcraft" research project at the University of Applied Arts in Vienna. His expertise is in the fields of parametric design and robotic fabrication.

Manora Auersperg is an artist and lecturer at the Department of Textiles – Free, Applied and Experimental Artistic Design, at the Institute of Art Sciences and Art Education, University of Applied Arts Vienna, since 2004. She studied Textile and Art Education in Vienna and Stage Costume Design in Berlin. With a thesis on the directed gaze—the relation between object, media and subject, she received her Master's degree. Her profession as Lecturer and her own artistic work are closely entwined. Interconnecting theory and practice, her artistic seminar „Fläche/ Körper/ Raum" refers to the subject of the human body in relation to the spatial and social context.

Sigurd Reiss studied mechatronics/robotics before joining Clever Contour, where he became CTO and project manager. Clever Contour GmbH is a research and development company in the third and last year of grant-aided R&D. The outcome of these developments is a novel manufacturing technology to create freeform elements out of individual bent semifinished plastic products without mold/formwork construction. The core of this technology is a patented bending system for the thermoplastic deformation of plastic strands in all degrees of freedom to realize freeform construction at a large scale. This technology, in combination with a specific developed software plugin for Rhino/Grasshopper, closes the process chain between design, manufacturing and end product. The manufacturing technology enables Clever Contour to realize individual freeforms in full scale up to two-thirds cheaper than using common manufacturing methods.